Final Report for Period: 06/2008 - 05/2009
Submitted on: 07/08/2009
Principal Investigator: Yao, Donggang .
Award ID: 0503138
Organization: GA Tech Res Corp - GIT
Submitted By:
Yao, Donggang - Principal Investigator
Title:
CAREER: Rapid Production of Plastic Microstructures

Project Participants

Senior Personnel

Name: Yao, Donggang
Worked for more than 160 Hours: Yes
Contribution to Project:

Post-doc

Graduate Student

Name: Xie, Zhe
Worked for more than 160 Hours: Yes
Contribution to Project:
Mr. Zhe Xie was working on the characterization of microscale polymeric flows during the fiscal years of 2003-2005.

Name: Nagarajan, Pratapkumar
Worked for more than 160 Hours: Yes
Contribution to Project:
Mr. Pratapkumar Nagarajan was working on polymer micro molding. He was supported by by the NSF grant during the fiscal year of 2005-2006.

Undergraduate Student

Technician, Programmer

Other Participant

Research Experience for Undergraduates

Name: Woo, Katherine
Worked for more than 160 Hours: Yes
Contribution to Project:
Ms. Katherine Woo was supported by the REU supplement for the summer research in 2005. She was working on biomimetic polymer surfaces. Particularly, she identified that the biological surface of dung beetle is an excellent applications of the micro molding technology. Later, a new method was developed for rapidly transfering the biological surface structures of the dung beetle to polymer substrates.

Name: Abbott, Kathryn
Worked for more than 160 Hours: Yes
Contribution to Project:
The student was supported by REU as a summer researcher in 2006. She and Mr. Pratapkumar Nagarajan, a graduate student, worked together on injection molding microstructured polymers.

Organizational Partners

Other Collaborators or Contacts

Collaborators

Professor Allen Yi
Industrial, Welding, and Systems Engineering
210 Baker Systems
1971 Neil Ave
Columbus, OH 43210

Professor Byung H. Kim
Department of Mechanical & Industrial Engineering
University of Massachusetts Amherst
160 Governors Drive
Amherst, MA 01003

Activities and Findings

Research and Education Activities:

The major research and educational activities include:
- Developed a room-temperature embossing process.
- Developed a two-station embossing process for rapid fabrication of polymer microstructures.
- Developed a micro molding method for rapidly transferring biological surface topography to polymer substrates.
- Developed a rubber-assisted embossing process for structuring very thin polymer films.
- Developed a through-thickness embossing process for fabrication of discrete microparts.
- Conducted fundamental studies of the processes developed, involving rheology, process analysis, modeling and simulation.
- Made more than 30 presentations at major conferences and to the industry and other universities, regarding polymer micromolding and micro rheology.
- Fourteen journal papers (directly resulted from the finding of this project) were published or accepted, and two additional papers are being prepared.
- About 15 conference papers regarding polymer microfabrication and micro rheology were published or accepted.

Findings:

The major findings include:
- Polymer microfeatures can be rapidly produced using the room-temperature embossing process.
- By using the two-station approach, rapid thermal response of the embossing die can be accomplished.
- Micro rubber forming can be effectively used for structuring very thin polymer films.
- With a through-thickness action, discrete microparts can be fabricated in a single step operation.
- Biological structures, e.g., dung beetle surface features, can be rapidly transferred to polymer substrates using micro molding techniques.
- Self aligned disk flow can be formed in micro gaps in the self-aligned disk-flow micro rheometer.
- The self-aligned disk-flow rheometry was verified using different testing fluids including Newtonian and non-Newtonian liquids.
- Accurate characterization of the rheological behavior of the embossing polymer near the transition temperature is critical to the success of a predicative model in embossing based processes.

Training and Development:

Two graduate students and two undergraduate students participated in the research project of 'Rapid Production of Plastic Microstructures' as research assistants. The students were trained in the field of polymer microfabrication which is an interdisciplinary area. The PI also integrated polymer microfabrication to two of the courses he has been teaching, namely, Manufacturing Processes and Polymer Processing (both at undergraduate and graduate levels). The lectures on polymer microfabrication help students gain an insight into the cutting edge frontier in miniaturization science and engineering.

Outreach Activities:

The PI gave presentations on polymer microfabrication to companies, universities, and other groups who are interested in the related technology.

Journal Publications

Nagarajan, P; Yao, D; Ellis, TS; Azadegan, R, "Through-thickness embossing process for fabrication of three-dimensional thermoplastic parts", POLYMER ENGINEERING AND SCIENCE, p. 2075, vol. 47, (2007). Published, 10.1002/pen.2092

Yao, DG; Kuduva-Raman-Thanumoorthy, R, "An enlarged process window for hot embossing", JOURNAL OF MICROMECHANICS AND MICROENGINEERING, p. , vol. 18, (2008). Published, 10.1088/0960-1317/18/4/04502

Yao, DG; Nagarajan, P; Li, L; Yi, AY, "A two-station embossing process for rapid fabrication of surface microstructures on thermoplastic polymers", POLYMER ENGINEERING AND SCIENCE, p. 530, vol. 47, (2007). Published, 10.1002/pen.2072

Nagarajan, P; Yao, DG, "Rubber-assisted micro forming of polymer thin films", MICROSYSTEM TECHNOLOGIES-MICRO-AND NANOSYSTEMS-INFORMATION STORAGE AND PROCESSING SYSTEMS, p. 251, vol. 15, (2009). Published, 10.1007/s00542-008-0680-

Yao, DG; Nagarajan, P; Li, L; Yi, AY, "A strategy for rapid thermal cycling of molds in thermoplastic processing", JOURNAL OF MANUFACTURING SCIENCE AND ENGINEERING-TRANSACTIONS OF THE ASME, p. 837, vol. 128, (2006). Published, 10.1115/1.233585

Yao, DG; Kim, B, "Scaling issues in miniaturization of injection molded parts", JOURNAL OF MANUFACTURING SCIENCE AND ENGINEERING-TRANSACTIONS OF THE ASME, p. 733, vol. 126, (2004). Published,

Yao, DG; Nagarajan, P, "Cold forging method for polymer microfabrication", POLYMER ENGINEERING AND SCIENCE, p. 1998, vol. 44, (2004). Published, 10.1002/pen.2020

Yao, DG; Xie, Z; Zou, Q, "Device with a self-aligned microgap for studying microscale flows", REVIEW OF SCIENTIFIC INSTRUMENTS, p. , vol. 76, (2005). Published, 10.1063/1.190474

Nagaraja, P; Yao, DG, "Rapid pattern transfer of biomimetic surface structures onto thermoplastic polymers", MATERIALS SCIENCE & ENGINEERING C-BIOMIMETIC AND SUPRAMOLECULAR SYSTEMS, p. 794, vol. 27, (2007). Published, 10.1016/j.msec.2006.08.02

Kimerling, TE; Liu, WD; Kim, BH; Yao, DG, "Rapid hot embossing of polymer microfeatures", MICROSYSTEM TECHNOLOGIES-MICRO-AND NANOSYSTEMS-INFORMATION STORAGE AND PROCESSING SYSTEMS, p. 730, vol. 12, (2006). Published, 10.1007/s00542-006-0098-

Yao, D; Virupaksha, VL; Kim, B, "Study on squeezing flow during nonisothermal embossing of polymer microstructures", POLYMER ENGINEERING AND SCIENCE, p. 652, vol. 45, (2005). Published, 10.1002/pen.2032

Yao, D; Nagarajan, P; Ramasubramani, KRT, "Constant temperature microfeature embossing with slowly crystallizing polymers", INTERNATIONAL POLYMER PROCESSING, p. 375, vol. 22, (2007). Published,

Yao DG, Chen SC, Kim BH, "Rapid thermal cycling of injection molds - an overview on technical approaches and applications", Advances in Polymer Technology, p. 233, vol. 27, (2009). Published,

Kuduva-Raman-Thanumoorthy, Yao DG, "Hot embossing of discrete microparts", Polymer Engineering and Science, p. , vol. , (2009). Published, 10.1002/pen.21422

Yao DG, Nagarajan P, "Uniform shell patterning using rubber assisted hot embossing process - Part I: Experimental study", Polymer Engineering and Science, p. , vol. , (2009). To be submitted (in July 2009),

Yao DG, Nagarajan P, "Uniform shell patterning using rubber assisted hot embossing process - Part II: Modeling and process analysis", Polymer Engineering and Science, p. , vol. , (2009). To be submitted (in July 2009),

Books or Other One-time Publications

D. Yao, "Micromolding", (2009). Book, Published
Editor(s): S. Thomas and W.M. Yang
Collection: Advances in polymer processing: macro- to nano- scales
Bibliography: Woodhead Publishing Limited

Donggang Yao, "Polymer micromolding/forming processes", (2010). Book, In preparation
Editor(s): Muammer Koç and Tugrul Özel
Collection: Micro-Manufacturing: Design and Manufacturing of Micro-Products
Bibliography: John Wiley and Sons, Inc.

Web/Internet Site

Other Specific Products

Contributions

Contributions within Discipline:

The major contributions within discipline from the research conducted include:
- A room-temperature embossing process for rapid production of plastic microfeatures.
- A two-station embossing process for rapid thermal response processing of plastic microfeatures.
- A micro rubber embossing processing for rapid structuring of very thin polymer films.
- A protocol for rapidly transferring biological features to polymers.
- A through-thickness embossing process for fabricating discrete microparts.
- A self-aligned disk-flow rheometry for microscale flow characterization.
- Improved understanding on the role of rheological behavior of polymer in polymer microfabrication.

The capability in characterizing and modeling microscale polymeric flows will provide a fundamental understanding of polymer microfabrication. The integrated research and education program will provide educational opportunities for students to work on leading edge research projects in polymer microfabrication.

Contributions to Other Disciplines:

The technology for rapid production of high-aspect-ratio microstructures will impact significantly in the fast growing telecommunication and biomedical industries.

Contributions to Human Resource Development:

Contributions to Resources for Research and Education:

Contributions Beyond Science and Engineering:

Conference Proceedings

Kuduva-Raman-Thanumoorthy, R;Yao, DG, DISCRETE MICROPARTS PRODUCTION USING THROUGH-THICKNESS HOT EMBOSSING AND RUBBER-ASSISTED EJECTION, "OCT 07-10, 2008", MSEC 2008: PROCEEDINGS OF THE ASME INTERNATIONAL MANUFACTURING SCIENCE AND ENGINEERING CONFERENCE 2008, VOL 2, : 377-383 2009

Yao, DG;Nagarajan, P;Ramasubramani, KRT, Constant temperature embossing of amorphous poly(ethylene terephthalate) films, "OCT 15-18, 2007", PROCEEDINGS OF THE ASME INTERNATIONAL CONFERENCE ON MANUFACTURING SCIENCE AND ENGINEERING - 2007, : 151-155 2007

Nagarajan, P;Yao, DG;Ellis, TS;Azadegan, R, Close-die embossing of multichannel waveguides, "OCT 15-18, 2007", PROCEEDINGS OF THE ASME INTERNATIONAL CONFERENCE ON MANUFACTURING SCIENCE AND ENGINEERING - 2007, : 157-161 2007

Yao, DG;Yi, AY;Li, L;Nagaraj, P, Two-station embossing process for rapid fabrication of polymer microstructures, "NOV 05-11, 2005", Micro-Electro-Mechanical Systems - 2005, 7: 131-132 2005

Categories for which nothing is reported:

Organizational Partners

Any Web/Internet Site

Any Product

Contributions: To Any Human Resource Development

Contributions: To Any Resources for Research and Education

Contributions: To Any Beyond Science and Engineering